Proposal for a SCOR working group:

Understanding the global impacts and implications of range-shifting species in marine systems

SUMMARY

Changes in the distribution and abundance of marine species are being reported around the globe; however, much of the present scientific focus has been on documenting these biological responses. Less well recognised is that many of the changes will affect the utilisation of marine resources with ramifications that range from fishers' profitability and livelihoods to food security, poverty and social cohesion. Species 'range shifts', have been documented from across polar, temperate and tropical regions, in both developed and developing countries, and are considered one of the most significant and immediate effects of global warming in the marine domain. Nevertheless, range shifts will not occur uniformly around the world as climate change is not impacting all areas equally. Regions where ocean warming is occurring most rapidly (marine hotspots) represent an opportunity to quickly advance our understanding of current and likely future changes. Synthesising available data on biological responses and subsequent human impacts (economic, social and governance) across marine hotspots will provide the basis for a comprehensive assessment of the dynamics and implications of range-shifting species. The major challenge addressed by the proposed working group is to identify key issues for marine resource management and governance arising from predicted marine species range shifts and provide a framework for developing contextually relevant adaptation options. This will be achieved by collating and analysing the latest biophysical and ecological data from the fastest warming global regions to generate a stronger understanding of the mechanisms that regulate range shifts and the traits that favour range shifts. This will provide the basis for predictions of potential consequences of range shifts and the development of appropriate adaptation options to assist communities, industry and governments to reduce negative impacts and maximise opportunities.

RATIONALE, SCIENTIFIC BACKGROUND AND SIGNIFICANCE

Climate change is considered one of the greatest ecological, economic and social challenges of our time[1,2]. The impacts of climate change are being felt around the globe, in developed and in developing countries, on land and in the ocean. Recent work has suggested that given observed emission and climate trends[3] planning for adaptation to a 4°C temperature rise is prudent [4,5]. Along with the political and logistical complexity surrounding mitigation solutions, it is critical to recognise the enormity of the global adaptation challenge. Adaptation to the effects of predicted warming will be a complex, difficult and multi-dimensional undertaking, but one that is necessary for lessening the impacts of climate change in a warming world. Our understanding of climate change impacts in the ocean has lagged behind that of terrestrial systems[6]. Likewise, adaptation efforts to date have focused on terrestrial systems[7], with the options for adaptation in ocean systems largely neglected.

The oceans are the earth's main buffer to climate change, absorbing up to 80% of the heat and 50% of the atmospheric carbon emitted[8,9,10], and thus suffer the double effect of warming and ocean acidification[11,12]. Changes in air and sea temperatures, rainfall, ocean acidification, sea level, and wind patterns are all contributing to modifications in productivity, distribution and phenology of marine species, affecting ecosystem processes and altering food webs[13,14,15]. The world's oceans provide close to 90% of the world's harvestable aquatic resources and fishing activity affects countries in a range of ways from food security and poverty, to regional and national balance sheets. In 2006 the global production from fishing and aquaculture combined reached approximately 144 million tonnes, of which 110 million were for human consumption. Fish provided more than 2.9 billion people with at least 15% of their average per capita animal protein intake, with figures exceeding 18% for low income food deficient countries[16]. Fisheries and aquaculture are a significant source of protein, income, or family stability for around 520 million people[17,18,19]. In 2006, an estimated 43.5 million people were directly engaged, part time or full time, in primary production of fish either in capture from the wild or in aquaculture, and a further four million people were engaged on an occasional basis[20].

With escalating demands in developing countries and a rapidly increasing human population, the global demand for seafood products will intensify[21,22]. Identifying the opportunities and threats from climate change, and developing

adaptation options is essential to optimising the benefits that society can continue to derive from the goods and services provided by marine resources.

Early warning of detrimental changes in marine resources provides communities with an opportunity to minimise costs associated with restructuring as well as social tensions (e.g. increased poverty, income redistribution and resource allocation). Early detection of biological responses to climate change will also identify emerging opportunities – for resource dependent communities it is critical these opportunities are identified early and managed appropriately. By synthesising existing data on range shifting species from the world fastest warming regions and predicting the spatial and temporal nature of future range shifts, outcomes from the proposed working group will enable resource users and managers to make informed decisions on their futures.

WHY RANGE-SHIFTING SPECIES?

One of the most widely documented impacts of climate change in marine systems is the shift in the distribution and abundance of animals as waters warm[23,24]. Range shifts in marine taxa have been described for waters around all continents, including Antarctica, and the Pacific Islands[25, 26]. These 'range shifts' bring with them challenges for governments, resource users and coastal communities, particularly when they cross jurisdictional boundaries. Although the biophysical changes have been documented in some regions (e.g. SE Australia), limited attention has been focused on options for adaptive management and governance in the presence of range-shifting species or for identifying options capable of supporting communities as their resource base changes.

The un-replicated nature of species' range shifts renders attribution of causality notoriously difficult[27]. However, some 75% of marine range shifts reported in the peer-reviewed literature have been polewards in direction – symptomatic of broad-scale environmental changes such as those predicted under global climate change scenarios[25]. In light of even the most conservative future climate change projections[28], coupled with the available evidence that climate change is likely responsible for shifts in many species' biogeographic ranges, more research is needed to understand the full extent of realised and potential future range shifts in marine taxa, and in particular the role that climate change plays in these shifts[29]. Because range shifts effect the distribution and abundance of harvested marine resources, as well as the dynamics of the ecosystems that underpin the productivity of marine resources, examining the diverse consequences of climate change-induced marine range shifts is critical. Although range shifts have been documented in the marine environment, far fewer studies consider the mechanisms underpinning range-shifting dynamics[30,,31], and even fewer the socioeconomic consequences or optimal management responses. Likewise, the appropriateness of existing or potential management responses has not been comprehensively explored[32]. As the global climate continues to change, range shifts driven by this globally ubiquitous process will likely broaden in both number and geographic extent. Considering the ecological, socioeconomic, and management implications of these changes before they occur is essential to mitigating their negative effects and developing effective adaptive response strategies and to seize opportunities.

WHY HOTSPOTS?

While water temperature is the major driver of distribution, abundance, phenology and life-history of marine species[33,34], it is only one climate change driver of biological change, with other drivers including sea-level rise, circulation changes, acidification, stratification change, salinity, upwelling and nutrient supply. Range shifts can also potentially occur via a number of non-mutually exclusive pathways, including environmental changes leading to latitudinal changes in range limits or alteration in depth ranges[35]; changes in current patterns leading to dispersal of organisms to new locations; and/or ecological changes leading to opening of formerly occupied niche space beyond former range limits[36].

The oceans are not warming evenly and those areas that are warming the fastest (i.e. marine hotspots) will become the world's natural 'early warning' laboratories to provide the knowledge and ultimately the tools to enable us to adapt wisely, efficiently and effectively to meet the challenges of a warming environment.

Based on historical (last 50 years) and projected (next 50 years) rates of ocean warming, 24 regional hotspots – areas that are warming faster than 90% of the oceans – have been identified[37]. These hotspots occur in all regions of the globe, from polar to tropical, and affect developed and developing countries. These regions are expected to provide early evidence of the response by natural resource systems to climate change and thus provide the most comprehensive understanding of the impacts of global warming in marine environments. In addition to providing the earliest examples of change, they will also provide the first opportunity to validate model predictions and evaluate the success of adaption options. These examples are urgently required to enable managers to prepare for climate change and to instil greater community confidence in the need for adaptation. There is consequently a critical need for a coordinated approach to impact and adaptation research in hotspots, encompassing the broadest range of ecosystem and resource types, with a commitment to sharing pertinent insights regarding impacts and adaptation.

These marine climate change hotspots represent a natural and replicated laboratory for assessing climate change impacts and developing, evaluating and implementing adaptation options to cope with a changing future. As such, synthesising outcomes from across these hotspots will also facilitate accelerated learning and indicate sensible pathways for maximising adaptation and minimising impacts of climate change for other marine regions. A systematic approach in the analysis and monitoring of information from these regions will therefore facilitate the advancement of adaptation science globally.

TERMS OF REFERENCE / OUTLINE OF PROJECT, INCLUDING WORKSHOPS

Changes in the abundance and distribution of marine resources will have biological, social and economic implications around the globe. The proposed SCOR Working Group will provide the most comprehensive analysis to date of the dynamics and implications of marine range shifts to provide researchers, industry, communities and governments with the knowledge to optimise the environmental, economic and social values from climate-induced range shifting species. We have assembled an international and interdisciplinary team to:

1. Synthesise the latest biophysical and ecological data to generate a thorough process-based understanding of recent range shifts in key global marine hotspots.
2. Synthesise the information from global hotspots to determine the generic similarities and specific differences across hotspot regions and to validate hypotheses regarding the mechanisms that regulate range shifts, the traits that favour range shifts and how communities, industry and governments are adapting.
3. Develop projections of likely future range shifts in key fisheries and biodiversity resources in a range of hotspot regions, based on the mechanistic understanding generated above.
4. Model the predicted effects of marine species range shifts on the social and economic components of linked human systems at various scales (e.g. fisher, fishery, community) and across marine resources in developed and developing countries.
5. Identify key challenges for marine resource management and governance arising from predicted marine species range shifts and provide a framework for developing contextually relevant adaptations

A GLOBAL APPROACH

This research team is well positioned to lead international initiatives. In April 2010 we organised a workshop '*Networking across global marine "hotspots"'* at the International symposium *'Climate Change Effects on Fish and Fisheries: Forecasting impacts, Assessing Ecosystem Responses, and Evaluating Management Strategies'* held in Sendai, Japan[38]. The most common observation from the hotspot regions was range shifts to higher latitudes and to deeper waters often resulting in an increased diversity and species richness of fishes. However, many of the species moving into temperate fishing grounds were of lower market value, whereas changes in ice cover in arctic regions resulted in increased yield from traditional fisheries through increased primary production[39]. Consensus from the workshop identified the benefits that could be achieved by synthesising, contrasting and comparing across locations as the best possible learning opportunity

to address climate challenges and that a network would provide a mechanism for capitalising, as efficiently and effectively as possible, on emerging information in a rapidly changing world.

The aim of this proposal is to bring together an inter-disciplinary team studying marine hotspots around the world to synthesise the existing and latest data available from these hotspot regions. This will be achieved through three workshops. The first will be in conjunction with the World Fisheries Congress in Edinburgh, Scotland (7–11 May 2012): *Sustainable Fisheries in a Changing World*. The second workshop will be held in late 2012/early 2013, located in South America, South Africa or Asia. The third and final workshop will be held in mid-late 2013.

Our team includes experts in oceanography, biology, ecology, social science, economics, modelling and policy, and spans highly experienced senior researchers through to dynamic early career researchers and PhD students. We are thus building international capacity to develop a comprehensive and process-based understanding of the implications of range shifts in marine systems – a critical issue in marine science that will only become more pervasive and ubiquitous as climate change continues. Importantly it is an issue that will alter international marine landscapes with resultant impacts on fishers and communities and thus requires the development of adaptation options and planned government responses.

The first workshop "*The changing demographics of global marine ecosystems: climate change and range shifts*" will be held at the World Fisheries Congress in Scotland, May 2012. We have already been selected as workshop convenors, under the banner of the *Global Network of Marine Hotpots*, following an invitation from the World Fisheries Congress and will refocus the workshop to reflect the SCOR initiative, providing global exposure to the SCOR Working Group. This multi-day workshop will have two main components 1/ "*Synthesis of range shifting species: what, where, when and why*" and will focus on improving our understanding of range shifts in key hotspot regions through the synthesis of existing physical (e.g. Global Observation Systems), biological, ecological and habitat mapping data associated with range shifting species. We will link biological observations with physical observations to delineate patterns, drivers and potential processes associated with range shifting species. This exploration will be mechanistic as well as statistical in nature and will utilise a variety of modelling approaches. The second part of this workshop will determine what emerging patterns and processes are evident from across the global hotspots. Importantly, we will be able to develop an understanding of what issues are generic across locations or specific to particular regions or conditions. Prior to the workshop, working group members will have developed a range-shifting species database (Deliverable 1) and collated the existing data and knowledge from as many of the 24 hotspot regions as possible. This will provide maximum opportunity at the workshop for participants to explore and model the data and to brainstorm ways of conceptualising and presenting the data to a variety of audiences/stakeholders. Participants will also populate the Global Marine Hotspots website (under development, www.marinehotspots.org) with the latest findings from the workshops and broader project (Deliverable 2).

By synthesising information across the fastest changing regions in the world, workshop 1 will assess the biological and physical traits that may be used to predict why some species have already shifted distributions more than others in response to recent climate change. We will compile data on the traits of species and 'receiving' ecosystems, and analyse variation in documented range shifts from major hotspots to determine whether such traits can predict differences in the rate or magnitude of recent range shifts. For example, range shifts may be positively related to traits allowing greater dispersal, intrinsic rates of increase (like generation time and reproductive output), and ecological specialisation/generalisation (diet breadth, climatic variance within the species' range). While there are large scale and general climate change global synthesises underway, they are very broad brush and conceptual in focus. Our synthesis will allow us to look at detail including an examination of systems and species. Our synthesis will be collated as a paper contribution to a high ranking journal (Deliverable 3) and will also be a bridge between small-scale experimental studies where the biological details are thought to be crucial and broad-scale modelling/synthesis efforts where the biological details are often ignored.

The second workshop "*The role of range shifting species in the future of global marine systems*" will take the understanding developed in the first workshop to predict the magnitude of range shifts of key fisheries and biodiversity resources under differing climate change scenarios, using global climate models (GCM's) and envelope modelling (e.g.

species distribution modelling). This workshop will include an analysis of the social and economic impacts of range shifting species on marine resources in a range of developed and developing countries. While we expect fewer existing studies on social and economic impacts, we will expect regional participants to source data from their respective sectors. The data required will be discussed during the first workshop. The output from this workshop will be the first comprehensive study on the consequences of range shifting species and the observed responses by communities, industries and governments that crosses polar, temperate and tropical domains as well as commercial, artisanal and subsistence fisheries. We will use these observations to predict future impacts from range shifting species from global ecosystem models. Outputs from this workshop will include a minimum of two major papers (Deliverable 4).

The third workshop *"Adapting to a brave new world: Lessons from the fastest warming marine regions in the world"* will focus on the management and governance of marine resources to optimise consumptive and conservation values in the presence of range shifts. The workshop will also investigate the potential to detect range shifts in a range of fished and non-fished species given the design of existing monitoring programs and include the evaluation of cost-effective global programs to detect range-shifts including the design of monitoring programs that are effective and consistent across regions. By synthesising across the fastest changing regions in the world this workshop will aim to demonstrate how fisheries are being impacted and how communities, industries and governments are adapting to ensure sustainable use of marine resources for current and future generations. Findings will be presented at an appropriate symposium or conference identified closer to 2013 with subsequent publication in an international journal (Deliverable 5).

Outputs from workshops will be developed into journal publications for *Nature: Climate change*, *Science*, *Ecology* and other high profile journals. Additionally, the project, and therefore SCOR and the participant institutes, will be showcased via the Global Network of Marine Hotspots website and forums. The website development has already been supported by the UNDP/GEF funded Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project and the on-going development of this network will enable the SCOR Working Group to foster long-term international high level collaborations.

SUMMARY OF DELIVERABLES

- Deliverable 1: Development of a database of the life history, population and ecosystem characteristics associated with observed marine range shifts from within global hotpots.
- Deliverable 2: Communication of the findings from the working group workshops and broader project via population of the Global Marine Hotspots website (under development, www.marinehotspots.org).
- Deliverable 3: Production of the synthesis paper '*The changing demographics of global marine ecosystems: climate change and range shifts',* which will examine the traits of range shifting species and 'receiving' ecosystems to determine whether such traits can explain differences in the rate or magnitude of recent range shifts.
- Deliverable 4: Publication of at least two papers on "*The role of range shifting species in the future of global marine systems*". These papers will develop predictions for range shifts and assess the likely socio-economic consequences of these in developed and developing countries.
- Deliverable 5: Production of a synthesis paper focusing on the management and governance of marine resources to optimise consumptive and conservation values in the presence of range shifts, "Adapting to a brave new world: Lessons from the fastest warming marine regions in the world".

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PROPOSED PARTICIPANTS

Full members	Institute	Country	Specialisation	Regional hotspot
Gretta Pecl (Co-Chair)	IMAS	Australia	marine ecology; fisheries adaptation; range shifts	SE Australia
Warwick Sauer (Co-Chair)	Rhodes University	South Africa	ecology; LME projects	SW Africa including Benguela System
Alistair Hobday	CSIRO	Australia	biological oceanography	SE & SW Australia
Thomas Wernberg (ECR)	UWA Oceans Institute	Australia	biogeography; physiology	SW Australia
Nicholas Dulvy	Simon Fraser University	Canada & UK	biodiversity; range shifts	North Sea and Canadian hotspots
Amanda Bates (ECR)	Deakin University	Canada & Australia	macroecology; range shifts	Global syntheses
Tom Okey	West Coast Aquatic Management Board	Canada	marine ecology	Bering Sea and North West America
Janet Nye (ECR)	US Environmental Protection Agency	USA	fisheries; range shifts	North East America
Stewart Frusher	IMAS	Australia	fisheries science; change adaptation	SW & SE Australia
Yury Zuenko	Pacific Fisheries Research Center	Russia	biological oceanography	Eastern Russia and Sea of Japan

Associate members	Institute	Country	Specialisation	Regional hotspot
Satoshi Nojima	Kyushu University	Japan	biodiversity	Southern Japan
Dan Smale (ECR)	University of Western Australia	Australia	biodiversity; EBFM	SW Australian
Ben Radford (ECR)	Australian Institute of Marine Science	Australia	biodiversity; spatial modelling	SW Australian
Neil Holbrook	University of Tasmania	Australia	physical oceanography; climate change science; adaptation	South Pacific region
Marcus Haward	Antarctic CRC	Australia	governance	Global
Sarah Jennings	University of Tasmania	Australia	economics; adaptation	SW & SE Australia
Graham Edgar	IMAS	Australia	ecology	Galapagos Islands
Beth Fulton	CSIRO	Australia	ecosystem modelling	Global
Nikki James	South African Institute for Aquatic Biodiversity (SAIAB)	South Africa	aquatic biology	SW Africa including Benguela System
Monica Mwale	South African Institute for Aquatic Biodiversity (SAIAB)	South Africa	fish genetics	SW Africa including Benguela System
Warren Potts	Rhodes University	South Africa	fisheries ecology	SW Africa including Benguela System
Jonathan Fisher (ECR)	Fisheries & Oceans Canada	Canada	macroecology	Canada
José H. Muelbert	Institute of Oceanography at FURG	Brazil	Biological oceanography	Brazil
E. Vivekananda	Central Marine Fisheries Institute	India	Fisheries science	Southern India

PhD students	Institute	Country	Specialisation	Regional hotspot
Jennifer Sunday	Simon Fraser University	Canada	macroecology	North America
Mike Litzow	IMAS	Australia	regime shifts	North America &

SHORT BIOGRAPHICAL PARAGRAPH FOR EACH PARTICIPANT (alphabetical)

Dr Amanda Bates is a post-doctoral ecologist with an interest in the role that environmental thresholds play in regulating the distribution, abundance and functioning of ectotherms in an era of climate change. Dr Bates has studied thermal tolerances in diverse organisms (e.g., bacteria, algae, invertebrates and fish) from Antarctica to the deep sea to advance both general ecological theory and applied management issues. During this time, she has been privileged to work with world-experts in the field of thermal physiology at some of the best institutions in the world including Harvard University (USA). At present, Dr Bates is working with collaborators to generate a theoretical framework for predicting the range responses of ectotherms to warming environmental temperatures with the goal of producing high-impact, widely read manuscripts.

Dr Nicholas Dulvy is a Canada Research Chair in Marine Biodiversity and Conservation and Co-Chair of the International Union for the Conservation of Nature's Shark Specialist Group, a global network of 160 scientists and experts with the mission to promote the long-term conservation and management of the world's sharks, rays and chimaeras. Dr Dulvy works on the ecological, economic and social impacts of climate change in marine ecosystems. He is known for providing some of the first evidence that marine organisms are deepening in response to climate change and for mapping the national vulnerability of the fisheries sectors of 132 countries to global climate change.

Associate Professor Graham Edgar's recent research interests primarily involve the investigation of broad temporal- and spatial-scale patterns of human impact on the marine environment, including fishing, climate change, introduced and invasive taxa, oil spills and fish farm effluent. Through studies disseminated in conference talks and over 100 reviewed journal articles, books, book chapters and edited conference proceedings, Dr Edgar has made major contributions internationally within the fields of marine ecology and conservation, in particular through studies of interactions between macrofaunal invertebrates, fishes and plants, through clarifying important metabolic-based regularities in faunal communities, and through assessment of threats to marine biodiversity. His contributions in the field of marine conservation science were recognised internationally by my selection as Director of Marine Research and Conservation at the Charles Darwin Research Station, Galapagos Islands, Ecuador, a position responsible for 50 employees, students and volunteers (2000-2002). Recent studies have primarily involved investigation over time of large-scale human impacts on marine ecosystems (in Tasmania, WA, SA, Victoria, NSW and the eastern tropical Pacific), including effects of fishing, sedimentation, oil spills, introduced species and aquaculture. A particularly notable aspect of recent studies is that they involve huge spatial, temporal and taxonomic scales, in some cases (e.g. empirical analysis of MPA effects) greater than any other previously attempted worldwide These studies have been particularly innovative in showing that studies at continental geographic scales, where outcomes of broad generality are deduced, can be conducted at low cost. His scientific papers are highly regarded and widely cited in the global ecological literature.

Associate Professor Stewart Frusher leads the Climate Change Theme of the Tasmanian Aquaculture and Fisheries Institute (TAFI) at the University of Tasmania. He led the successful inter-disciplinary bid for the Australian Government's Department of Climate Change National Coastal Vulnerability assessment case study on fisheries. He is also the co-leader of the Marine Biodiversity and Resources node of the National Climate Change Adaptation Research Facility's Marine Biodiversity and Resources Network. Assoc Prof Frusher was co-convener of INTECOL's symposium on Climate Change, Changing Opportunities in Southern Coastal Temperate Ecosystems and co-convener of the PICES/ICES Workshop on Networking across global marine 'hotspots' at the Climate Change Effects on Fish and Fisheries: Forecasting impacts, Assessing Ecosystem Responses, and Evaluating Management Strategies Symposium. He chaired the climate change sessions at the 8th International Conference and Workshop on Lobster Biology and Management (2008) and Recent Advances in Lobster Biology and Management (2010). Assoc Prof Frusher has over 30 years of experience in marine science, specialising in fisheries science. He has worked with fisheries from subsistence, artisanal to industrial. He is a regular reviewer for a range of fisheries and marine ecology international journals and reviewer for international research grant agencies. In 2002 Assoc Prof Frusher was award the Dean's Award for Research Excellence. He has published over 50 international publications and has been the recipient of $1.6 million in research grants as a Chief Investigator and $4.5 million as a partner investigator. Assoc Prof Frusher is recognised for his development of interdisciplinary studies through external funding support for the Coastal vulnerability assessment project (as mentioned above), 'Building Economic Capability to Improve the Management of Marine Resources in Australia' and 'Integrated simulation tools for the bio-economic assessment of renewable resource systems'. He has recently been award a large national project spanning south-eastern, western and northern Australia to develop 'A climate change adaptation blueprint for coastal regional communities' that also crosses the biophysical, social, economic and governance disciplines.

Dr Beth Fulton is a CSIRO science leader. She received her PhD from University of Tasmania in 2001, receiving a Dean's commendation for a PhD by research. Dr Fulton works extensively with marine ecosystem modelling. She developed *Atlantis* and co-

developed *InVitro*, which are used to support sustainable multiple use management options for marine environments in Australia and internationally. These tools help identify sensible development and resource use with the conservation of biodiversity and functioning marine ecosystems. Dr Fulton's current work involves implementing ecosystem-based models for regional-scale management strategy evaluation in Australia and internationally, modelling for understanding climate change effects and associated biodiversity and evolutionary shifts, leading CSIRO's marine ecological and ecosystem modelling group, and supervising two post-doctoral fellows and five graduate students. In 2010, Dr Fulton was awarded a prestigious Pew Fellowship in Marine Conservation. She has also been awarded: the Science Minister's Prize for Life Scientist of the Year in 2007.

Associate Professor Marcus Haward is a political scientist specialising in oceans governance and marine resources management. He is internationally recognised as a leader in his field as demonstrated by research collaborations and number of publications including books and book chapters. Assoc Prof Haward is also an active supervisor of graduate students, having supervised 28 PhD students and two research MA students to completion since 1993. He is currently teaching in the School of Government, University of Tasmania with appointments to the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) and the Adaptation Research Network for Marine Biodiversity and Resources under the National Climate Change Adaptation Research Facility. He has over 137 publications covering fields such as Antarctica, fisheries management, and coastal and oceans governance as well as Australian politics and government.

Dr Alistair Hobday is Principal Research Scientist at CSIRO Marine and Atmospheric Research in Hobart and leads the Marine Climate Impacts and Adaptation area within CSIRO. He has raised the profile of climate change for Australian marine systems, via workshops, conferences, and collaborative initiatives. Together with his team, Dr Hobday ran the first National Symposia on Climate Change and Marine Life; and he has been co-editor of two recent reports on the impacts of climate change on (i) fisheries and aquaculture, and (ii) Australian marine life. Recently Dr Hobday's team delivered the 'ecosystems' chapter to the Department of Climate Change National Coastal Vulnerability Assessment. Dr Hobday and contributed to the IPCC 4th assessment report, and to the 5th. He is co-chair of the IMBER program CLIOTOP (Climate Impacts on Oceanic Top Ocean Predators) program, was a member of the National Drafting Team for the National Adaptation Plan for Marine Biodiversity and Resources, and is a node leader for the National Adaptation Research Network for Marine Biodiversity and Resources. He also leads the biophysical work area within the fisheries and climate change South-east Australia Program (SEAP). Dr Hobday has been published 70 peer-reviewed papers, and is an expert reviewer for the ARC, the National Biodiversity Strategy, the National Climate Change Action Plan for Fisheries and Aquaculture, and overseas organisations including the Marine Stewardship Council and the National Marine Fisheries Service (USA). He has also provided national climate change research and policy advice for AFMA, BRS, and FRDC, as well as state agencies including Tasmania, Victoria, and South Australia.

Associate Professor Neil Holbrook is one of the world's leading authorities on the upper ocean dynamics and climate of the southwest Pacific Ocean, making important contributions to their understanding during the past 13 years. Assoc Prof Holbrook (1) provided the first published quantification of the multi-decadal upper ocean warming in the southwest Tasman Sea, and its contribution to steric sea level rise (Holbrook and Bindoff 1997); (2) demonstrated the significant modulating effect of El Niño-Southern Oscillation (ENSO) and decadal variability throughout the southwest Pacific Ocean, that connects through the East Australian Current and Tasman Front (Holbrook et al. 2005), and affects subtropical mode water formation (Holbrook and Maharaj 2008); and (3) discovered the essential role of forced Rossby waves on seasonal variations in southwest Pacific upper ocean temperatures (Holbrook and Bindoff 1999). Following this, Assoc Prof Holbrook developed a research program and built a research group (largely of postgraduate students) to investigate the role of oceanic Rossby waves on interannual-to-decadal scale climate variability in the South Pacific. This research has improved our understanding of (4) the mechanisms underpinning Pacific Ocean interannual dynamics (Perkins and Holbrook 2001); (5) interdecadal climate variability and predictability (McGregor, Holbrook and Power 2004, 2007, 2008, 2009ab); and (6) the importance of Rossby wave modes in the presence of bottom topography using satellite observations (Maharaj, Cipollini, Holbrook 2005; Maharaj, Cipollini, Holbrook, Killworth, Blundell 2007; Maharaj, Holbrook, Cipollini 2009). Most recently, Neil has led an important research direction demonstrating the strong and significant link between changes in the large-scale South Pacific climate and winds, East Australian Current intensity and sea level at the coast in Sydney Harbour (Holbrook 2010; Holbrook et al. 2010).

Dr Nikki James is employed as an Aquatic Biologist at the South African Institute for Aquatic Biodiversity (SAIAB) in Grahamstown South Africa, focusing on global change research. She is co-leader of a programme investigating the effects of climate change on sub-tropical Western Indian Ocean fish species. The study uses a climatic envelope method to explore the extent to which the range of selected shared fisheries species endemic to the subtropical WIO might shift in response to changes in the surrounding environment with climate change.

Dr Sarah Jennings is a natural resource economist with particular expertise in applied welfare analysis, including cost-benefit analysis and non-market valuation. Dr Jennings heads the School of Economics and Finance at the University of Tasmania. Her involvement in marine economics includes the evaluation of climate change impacts and adaptation strategies, and exploration of the behavioural responses of recreational fishers to climate-induced changes in the quality of recreational fishing opportunities and policies. Dr Jennings leads the national FRDC Building Capability in Fisheries Economics Project which involves providing research higher degree training in fisheries economics.

Mike Litzow, although recently commencing a PhD with QMS, has worked in the area of marine ecology in North Pacific ecosystems for 12 years. Mike has broad interests in ecological effects of fishing and climate change and using ecological theory concerning alternate stable states to understand threshold responses of exploited marine ecosystems to external forcing. He has 15 publications in high quality international journals including *Ecological Applications*, *Oceologia*, and *Fisheries Oceanography*.

Dr. José H. Muelbert has a Bachelor degree in Oceanography from Universidade Federal do Rio Grande (FURG-Brazil)), an MSc in Biological Oceanography from FURG and a PhD in Biological Oceanography from Dalhousie University (Canada). He is an Associate Professor at the Institute of Oceanography at FURG, where he acts as Vice-Director. Dr. Muelbert served at the Global Ocean Observing System (GOOS) Scientific Steering Committee (GSSC) between 2002 and 2006, and currently is the Co-chair os the Panel for the Implemention of Coastal Observations (PICO). His research interests involve physical-biological interactions in marine pelagic ecosystems, fish eggs and larvae, modeling of larval fish transport, and climate change. Dr. Muelbert is a Co-Pi in the the South American Climate Change (SACC) Consortium, an initiative sponsored by the IAI through the Cooperative Research Networks (CRN) Program (http://www.sacc.org.uy/). He is also the Vice-Coordinator for the Coastal Zone program of the Brazilian National Institute of Science and Technology (INCT) for Climate Change (http://www.zonascosteiras.com.br/).

Dr Monica Mwale is employed as an Aquatic Biologist at the South African Institute for Aquatic Biodiversity (SAIAB) in Grahamstown South Africa and, with Nikki James, leads a project focusing on the effects of climate change on sub-tropical Western Indian Ocean fish species. Monica specialises in genetic research, and specialises in the determination of genetic diversity in relation to the traits responsible for adaptation and the level of gene flow between populations, determined by their ability to migrate to more suitable habitats.

Dr Janet Nye is a fisheries ecologist who has documented shifts in distribution of Northeast US fish stocks and communities related to warming. Her current research attempts to understand the mechanisms behind these shifts in distribution, particularly the influence of fishing, climate change, and large scale oceanographic features. She is interested in incorporating large-scale oceanographic features into both single-species stock assessments and ecosystem assessments. She is also an expert in downscaling global climate models to forecast changes in the distribution and productivity of marine and estuarine organisms. She is currently a research ecologist at the US Environmental Protection Agency.

Dr Tom Okey is Director of Ecosystem Sciences for the West Coast Vancouver Island Aquatic Management Board. He is an Adjunct Professor in the School of Environmental Studies at the University of Victoria, Canada, and he holds a Pew Fellowship in Marine Conservation on the effects of climate change on Pacific marine life and ecosystems. His projects include the development of an Integrated Ecosystem Assessment for the West Coast of Vancouver Island as a case study for distinguishing the effects of climate change from other anthropogenic stressors in a coastal marine setting, and as a practical application for integrating ecosystem-based and multidisciplinary marine and ocean science with policy. Other recent initiatives include the development of international networks and collaborations for the development of marine climate impacts forecasting tools, and for the development of marine climate adaptation approaches. Dr Okey has been involved marine ecological studies in many areas of the Pacific during the last 24 years. He has worked in government, academia, the private sector, and with non-governmental conservation organisations conducting work ranging from small-scale ecological field experimentation to ecological and human health risk assessments to the development and expansion of fisheries and marine conservation programs to large-scale ecosystem modelling and assessments. His original training is in marine benthic disturbance ecology, but is more recently renowned for constructing high quality and highly articulated and trophodynamic models of marine ecosystems in settings throughout the world. Dr Okey has initiated and is otherwise involved in some meta-analyses of ecosystem models to understand the impacts of climate change and fisheries. He is the founder and Science Director of Conservation Science Institute.

Dr Gretta Pecl is a Fulbright Fellow and a Senior Research Fellow leading several projects within the Climate Change Impacts and Adaptation Theme at the Institute of Marine and Antarctic Studies. She is also a Research Fellow with the Australian Marine Adaptation Network (http://arnmbr.org/content/index.php/site/aboutus/). Dr Pecl's current research activity spans a range of topics including range extensions associated with climate change, evaluating adaptation options in socio-ecological systems, assessing population and fishery responses to climate change, and on using citizen science approaches for ecological monitoring and engagement (e.g.

www.REDMAP.org.au). She was lead author of the recent Australian Federal Department of Climate Change interdisciplinary report into the impacts and adaptation response options for the Tasmanian Rock Lobster Fishery (see http://www.climatechange.gov.au/en/publications/coastline/east-coast-rock-lobster.aspx), and the FRDC *Climate Change Risk Assessment for Key Marine Species in South Eastern Australia*. Dr Pecl's recent Fulbright Fellowship was undertaken in Alaska, a project developed specifically to facilitate collaboration and knowledge exchange between northern and southern hemisphere marine hotspot regions. She has 35 publications in high quality international journals including *Oecologia*, *Proceedings B*, *Global Environmental Change* and several feature articles in *Marine Ecology Progress Series*. In addition to her Fulbright, Dr Pecl has been awarded a 2010 UTAS 'Rising Star' and the Redmap project she leads has been nationally recognised with a 2010 Whitely award.

Dr Warren Potts is a senior lecturer at the Department of Ichthyology and Fisheries Science at Rhodes University and an honorary research associate of the South African Institute of Aquatic Biodiversity. He specialises in ecological research on linefish with particular emphasis on fisheries development, fisheries management and the impact of global change on fishery species. Dr Potts has led a research programs in Angola and South Africa and has extensive regional and international collaborative relationships. Dr Potts's publications include 18 peer reviewed articles in scientific journals, 9 scientific reports, 1 book chapter on the impact of climate change on inshore fishes in South Africa, numerous conference presentations and six popular articles. He has supervised 14 honours, four MSc students and lectured fishery field techniques, practical techniques, fish anatomy, statistics, fisheries management and limnology.

Dr Ben Radford is a spatial modeller with the Australian Institute of Marine Science and concurrently holds an adjunct research position at UWA. He gained his PhD in 2007 and his research has focused on applying novel modelling methods to areas ranging from the production of spatially explicit habitat models to the prediction of patterns of biodiversity based upon an understanding of biophysical surrogates and ecological processes. This work has been recognised with a number of awards such as the Victorian Coastal Council Annual Award for Innovation, the Australasian Hydrographic Society Award for recognition of scientific & technical achievement, The CRC Chair's Innovation Award for novel and unique interdisciplinary research and the State Coastal Conference Award for Excellence in Marine Research. To date Dr Radford has published 12 papers in journals such as *Journal of Biodiversity*, *PLoS One* and *Conservation Letters*.

Professor Warwick Sauer is Professor and Head of the Department of Ichthyology and Fisheries Science at Rhodes University in South Africa. His interests are in fisheries ecology and management, particularly in the translation of science into practical fisheries management. He serves on a number of management bodies, including the International Cephalopod Advisory Council, and has been involved in numerous regional research projects covering Sub Saharan Africa and the western Indian Ocean. Professor Sauer currently serves as a member of the Project Coordination Unit for the Agulhas and Somali Large Marine Ecosystem Project, and coordinates training and capacity building initiatives across the Agulhas region.

Dr Dan Smale is post-doctoral research fellow at the University of Western Australia. His research has documented how patterns of marine biodiversity vary over space and time, and has improved understanding of the processes that drive such variability. He completed his PhD with the British Antarctic Survey in 2008, after spending 5 years investigating the role of iceberg disturbance on the structure of benthic communities. This work culminated in a paper in *Science* and the 2008 'Law's Prize' for an outstanding contribution to polar science by an early career researcher. Dr Smale subsequently relocated to Australia to work on a large state-funded initiative to implement Ecosystem-Based Fisheries Management in the West Coast Bioregion. To date, he has published 21 papers on ecological datasets from Antarctica, Australia and the Seychelles, in journals such as *Science*, *PLoS One*, and *Diversity and Distributions*.

Jennifer Sunday has nearly finished her PhD and is interested in the distribution, ecology, and evolution of marine populations under natural and human-influenced environmental change. Through large-scale comparative work, Jennifer, Dr Bates and Dr Dulvy have revealed key differences in how terrestrial and marine ectotherms are distributed globally in relation to their thermal physiology, and indeed how their distributions have responded to recent climate change. Jennifer also leads a cross-university project addressing the potential for adaptive evolution in marine organisms under ocean acidification. Jennifer's PhD thesis at Simon Fraser University focuses on the historical climate-related range shifts, and processes leading population differentiation in marine dispersing animals.

Dr Thomas Wernberg is an Assistant Professor at the UWA Oceans Institute and a research fellow at the Australian Institute for Marine Science. His PhD in Marine Botany (UWA, 2003) and was awarded a Distinction (top 5%). DR Wernberg is a productive researcher who has published >50 research papers, and received $1.1M in funding predominantly as the lead CI of competitive grants. He is still early in his career, but is already gaining recognition for his contributions in climate related marine ecology. For example, in 2010 he was invited to present at a symposium on climate change at the International Seaweed Symposium in Mexico. Most recently, Dr Wernberg was invited to lead a review of marine climate change in temperate Australia for the 400th special issue of the *Journal of Experimental Marine Biology and Ecology* (Wernberg et al., in press, JEMBE). Previously, Dr Wernberg led the chapter on macroalgae and temperate reefs in the National Marine Climate Change Report Card (2009), and convened a working group on Climate Impacts on Marine Flora under the

ARC NZ Vegetation Function Network (2009). His current research focuses on the nexus between physiology, ecology and biogeography, with an emphasis on understanding the ecological costs of physiological adaptations (e.g., Wernberg et al., 2010, *Ecol Lett*, Wernberg et al. in press, *PLoS One*). Dr Wernberg has worked extensively throughout Australia's temperate waters and in the tropical Northwest (Ningaloo), and he is currently leading an international collaboration focused on understanding environmental drivers of kelp productivity through the Worldwide Universities Network.

Dr E. Vivekananda leads the ICAR Network Project "Impact, Adaptation and Vulnerability of Indian Marine Fisheries to Climate Change". He has contributed to the Second National Communication on Climate Change (NATCOM) to the Ministry of Environment & Forests in India. He has over thirty years of experience in marine fisheries, stock assessment and ecosystem analysis. He has served as a consultant for FAO in Stock Assessment, Prospects of Deep Sea Fisheries and Developing Vulnerability Indices for Marine Fisheries. He is a Task Force Member in the Bay of Bengal Large Marine Ecosystem Project of GEF and FAO.

Dr Zuenko Yury, D.Sc. is Head of the Japan Sea and North-West Pacific Oceanography Section, Pacific Fisheries Research Center (TINRO), Vladivostok, Russia. He graduated the State Marine Academy in Sankt-Peterburg in 1981 and worked in Pacific Fisheries Research Center in Vladivostok since 1985 as engineer, researcher, head of laboratory, and head of section. He got his Ph.D. degree in Far-Eastern Branch of Russian Academy of Science in 1995 on physical processes on the shelves of the Far-Eastern Seas. In the last decade, the main direction of his studies is fisheries oceanography, in particular in the Japan Sea. As one of these studies results, he has successfully defended the D.Sc. thesis on climate change influence on the Japan Sea ecosystem in Russian Hydrometeorological University in 2009.